of the greasy spot fungus into the mesophyll of orange leaves is very slow (8). In fact, for several weeks after the hyphae have penetrated the stomata, benomyl would not have to move more than a few cells deep to reach even the most advanced hyphal penetrations. When applied 6 days after inoculation, even a copper fungicide spray, which would normally be regarded as having only a protectant action, caused a slight reduction in disease severity (Table 2).

From the practical standpoint, benomyl should probably be regarded as having only limited systemic activity in fully expanded citrus leaves, at least in terms of the concentrations required to control greasy spot. Furthermore, the results from the field experiment showed that there is unlikely to be sufficient redistribution by rainfall of the fungicide from a sprayed upper leaf surface to an unsprayed lower leaf surface to affect greasy spot control appreciably. Good spray coverage of the lower leaf surface should therefore be regarded as just as essential with benomyl as it is with copper or oil for the effective control of greasy spot.

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EFFECT OF GROWTH REGULATORS ON THE RESPONSE OF CITRUS FRUIT TO CYCLOHEXIMIDE-INDUCED ABSCISSION

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Abstract. **Valencia orange trees were pretreated with the growth regulators, gibberellic acid and abscisic acid, and the growth retardant, SADH, before cycloheximide treatments. Pretreatments with gibberellic acid conditions the rind to produce less ethylene when cycloheximide is applied, whereas pretreatments with either abscisic acid or SADH conditions the rind to produce more ethylene when cycloheximide is applied. Since the mode of action of cycloheximide in causing the fruit to produce ethylene involves injuring the rind, it follows that gibberellic acid and abscisic acid must somehow affect the nature of the rind tissue, making it either more or less susceptible to rind injury.**

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With an Environmental Protection Agency label permitting sale of oranges treated experimentally with cycloheximide (CHI) since 1970, much experience in the field use of this chemical as an aid to mechanical harvesting has been gained. In 1970, Buttram (2), in field plots of an acre or more in size, demonstrated that early and midseason orange varieties in Florida can be readily harvested by machines, after application of 10 to 20 ppm CHI to the trees 5 days before harvest.

Some variability in the responsiveness of these early and midseason varieties to CHI treatments results from maturity, climatic, and soil factors; but, generally, CHI is highly effective on these varieties (2, 4, 12, 14). The response of 'Valencia' (*Citrus sinensis* Osb.) oranges to CHI treatment is extremely variable. During April, when Valencia orange trees are carrying young fruit of next year's crop, both the young and mature fruit are sometimes readily harvested by CHI treatment. But during May, when young fruit have developed some resistance to CHI injury, the mature fruit become difficult to loosen by

CHI treatment. Thus, the general use of CHI on Valencia oranges is not warranted.

Currently, there are two different research approaches to the 'Valencia' orange abscission problem: one involves the continued screening of chemicals in search of a chemical that successfully loosens mature Valencia fruit without injuring the young fruit (14); the other approach involves a study of ways to improve the abscission response of Valencia oranges to CHI treatment.

We know that the mode of action of CHI on fruit abscission lies in the ability of the chemical to make the fruit generate ethylene (3, 4) and it is the ethylene that turns on the synthesis of wall-modifying enzymes (9, 11) and other biochemical sequences essential for fruit abscission. However, little is known about seasonal, climatic, and varietal effects on the ability of the fruit to produce ethylene when treated with CHI.

Likewise, knowledge is lacking on factors involving the sensitivity of fruit to ethylene action on abscission. The growth regulator auxin is known to inhibit abscission as indicated by the prevention of preharvest drop of oranges by application of 2,4-D (6). However, it is questionable if much naturally occurring auxin exists in mature citrus fruit (7). Two other growth regulators, gibberellins (GA) and abscisic acid (ABA), are known to occur in mature oranges in Florida. The GA content increases and ABA decreases in 'Valencia' oranges during regreening (10). Therefore, we have investigated the effects of external application of these two and other growth regulators on Valencia oranges to determine their effects on levels of ethylene produced by CHI treatment.

Materials and Methods

Fifteen-year-old trees of 'Pineapple,' 'Parson Brown,' 'Hamlin' (*C. sinensis* Osb.), and Valencia orange on sour-orange rootstock were used for this investigation. In these tests, three trees were sprayed with each concentration of the test solutions. Generally, 10 gal. of test solution was adequate for wetting the foliage and fruit of the trees. The average value of the fruit removal force (FRF) of 10 fruit, selected at random on each of the three trees 6 days after treatment, was used as the index for the effect of the test solutions on loosening the fruit. The procedures used for ethylene measurements of the internal atmosphere of the fruit are the same as those described elsewhere (5).

The growth-regulator treatments applied to Valencia orange trees include 20 ppm gibberellic acid (GA_3) applied once on March 20; 200 ppm ABA applied once a week beginning on March 20 and continued through May; and 4,000 ppm succinic acid, 2,2,dimethylhydrazide (SADH), applied every 3 wk. beginning on March 20 and continued through May. Three pretreated and three untreated trees were sprayed with 20 ppm CHI May 1 and May 22.

Results

At the time of color break early in December, Hamlin, Parson Brown, and Pineapple oranges show about the same abscission response to CHI. The fruit-removal force (FRF) is lowered to about 7 lb., which is about 2 lb. above the threshold level (5 lb.) for good fruit abscission (Fig. 1). During January and February, the FRF values for CHI-treated 'Hamlin' and Parson Brown' oranges is reduced to 5 lb., while that for CHI-treated 'Pineapple' oranges is usually reduced to 2 lb. or less. In contrast to the good response of these early and midseason varieties, the response of 'Valencia' oranges to CHI is low in December, but gradually increases during the winter. However, during May, 'Valencia' oranges again become unresponsive to CHI.

Because of the good abscission response of the 'Pineapple' orange to CHI during February, we sprayed trees with a series of CHI solutions of very low concentrations, ranging from 0.5 to 10 ppm. A slight increase in ethylene production and fruit loosening occurred, even at the low level of 0.5 ppm of CHI (Fig. 2). With increasing concentrations of CHI, peak levels of ethylene in the fruit increased, with a maximum of 3.3 ppm in fruit treated with 10 ppm CHI. However, in the 'Valencia' orange treated with 20 ppm on May 1, the peak level of ethylene was well below 1 ppm (Fig. 3). Thus, one reason for the poor abscission response of 'Valencia' orange to CHI treatment was the apparent reduced capacity of the fruit to produce ethylene.

When 'Valencia' orange trees were sprayed with GA on March 20, and CHI was applied on May 1, there was a 50% reduction in both ethylene production and fruit loosening, as compared with CHI-treated fruit not receiving the supplemental GA treatment (Fig. 3). In contrast, when trees were sprayed with ABA (200 ppm at weekly intervals) before an application of CHI on May 1, there was a 100% enhancement in both ethylene production and in fruit loosening. Thus, ABA and GA seem to have

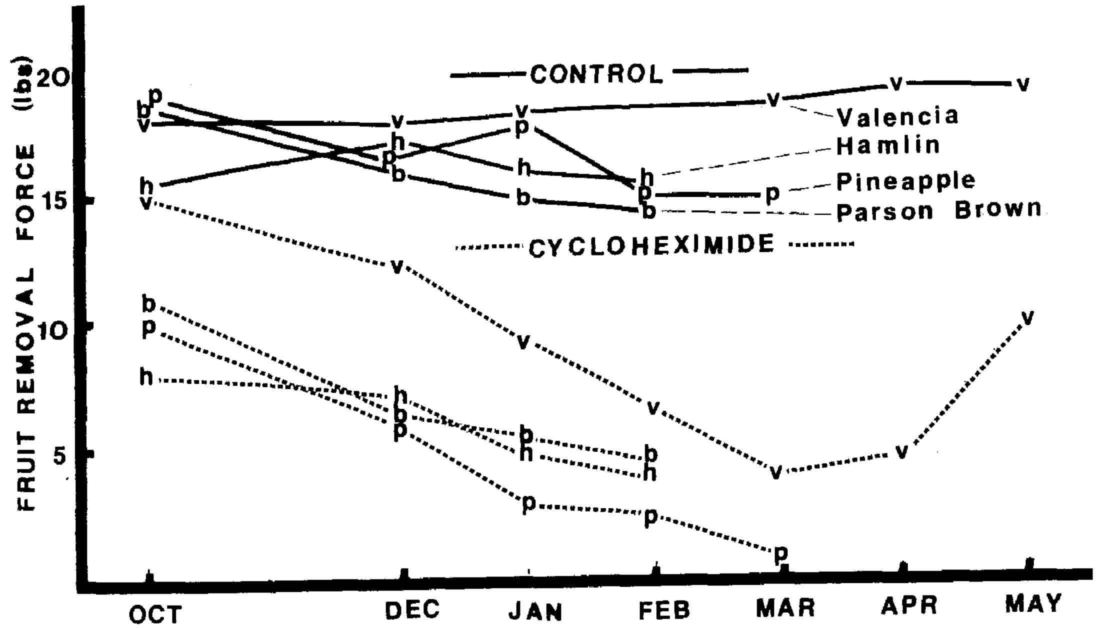

Fig. 1. Fruit removal force of 4 cultivars of sweet orange 7 days after treatment with 20 ppm CHI and controls at different months of the year.

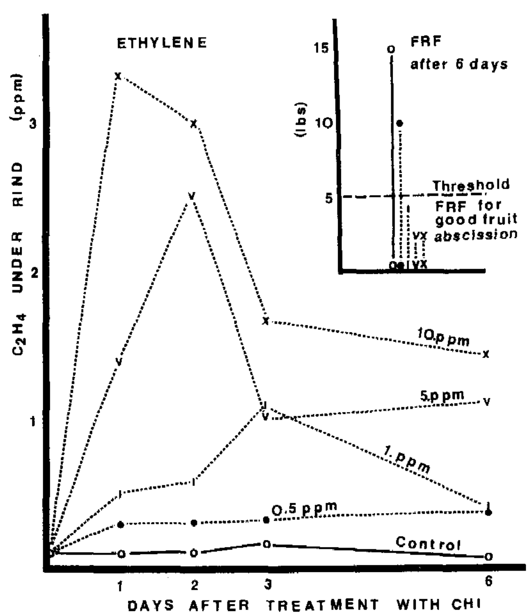

Fig. 2. Ethylene production & abscission response to low concentrations of cycloheximide Pineapple orange Feb. 29, 1972.

opposing effects on ethylene production by fruit treated with CHI. The SADH-supplemental treatment had about the same effect as ABA on ethylene production and fruit loosening.

Discussion

Recent investigations by Rasmussen (10) indicate that natural regreening and rejuvenation of the rind of Valencia oranges during April and May are associated with increases in the levels of endogenous GA and decreases in the levels of endogenous ABA. When exogenous application of ABA and GA are made to Valencia orange trees, in the experiments reported herein, the internal levels of GA and ABA are raised (10). The GA treatment enhanced regreening of the rind, while the ABA treatment promoted coloring, aging and softening of the rind.

The ABA and GA treatments did not promote ethylene production by the fruit, but GA conditioned the fruit to produce less ethylene when CHI was applied, and ABA conditioned the rind to produce more ethylene when CHI was applied. Since the mode of action of CHI in causing fruit to generate ethylene involves injuring the rind, it suggests that GA and ABA must somehow affect the nature of the rind tissue, making it either more or less susceptible to CHI injury.